



# **U. S. NAVAL SUBMARINE MEDICAL CENTER**

**Submarine Base, Groton, Conn.**

**REPORT NO. 481**

**A LONGITUDINAL STUDY OF ACUITY AND PHORIA AMONG  
SUBMARINERS**

**by**

**Donald O. Weitzman, Jo Ann S. Kinney, and  
Alma P. Ryan**

**Bureau of Medicine and Surgery, Navy Department  
Research Work Unit MF022.03.03-9019.11**

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**SUBMARINE MEDICAL RESEARCH LABORATORY  
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**Approved by:**

**Jack L. Kinsey, CAPT MC USN  
Director, SubMedResLaboratory**

**Approved and Released by:**

**C. L. Waite, CAPT MC USN  
Commanding Officer, SubMedCen**

## **SUMMARY PAGE**

### **THE PROBLEM**

To measure the visual acuity and phorias of a sample of 51 submariners and compare the results with the same tests performed on the same men in 1951.

### **FINDINGS**

Results of the comparison after the passage of 15 years showed the men to have poorer acuity now, both at far and near, and more esophoria than they did in 1951. The amount of the loss is greater than that predicted for men of their age group.

### **APPLICATIONS**

Results of this study will be of assistance in determining the need for improving the visual environment in submarines and the visual performance to be expected by men of different ages and with different lengths of submarine service.

### **ADMINISTRATIVE INFORMATION**

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work-Unit MF022.03.03-9019—Visual Performance and Requirements in Submarine and Other Underwater Operations. The present report was approved for publication on 12 September 1966 and designated as Report No. 11 on the indicated Work-Unit.

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## ABSTRACT

In 1951, a group of 1,064 submariners were given a battery of visual tests in order to assess the visual characteristics of the population at that time. A sample (51 individuals) of the original group was recently retested on the same battery, in order to assess the effects of long-term submarine duty (15 years) on vision.

It was found that certain changes had taken place over the 15-year period, most notably, a loss of visual acuity, at both near and far, and a tendency toward esophoria. While some decrement in vision is expected as a function of age, these changes are larger than that predicted for men of their age level.

The suggestion has been made previously that the confining nature of the submarine with the constant requirement for accommodation and convergence, might cause a visual impairment. This possibility, and other conceivable influences, will be evaluated in further longitudinal studies of submariners and non-submariners. Preventive measures will also be assessed.

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## INTRODUCTION

The visual acuity standards for submariners in the early 1950s were stringent, requiring unaided vision of 20/20 in each eye for officers, enlisted men in the deck group, ordnance, and seamen, and 20/25 for all others. A survey<sup>1</sup> of the visual characteristics of 1064 submariners was performed at that time and indicated the visual standards had been effective in selecting men with excellent vision. Of the men, 84% had 20/20 or better vision in each eye while only 4% fell below 20/30.

Nevertheless, there was an indication in the data that prolonged submarine service might cause some visual loss since the visual acuity of the men in service for longer periods of time was poorer than those with shorter records.<sup>2</sup> There was also an indication of increased esophoria for the submariners. While the acuity loss might be ascribed simply to an effect of age, it was argued that an age effect should not occur for men who were only about 25 years old. The tentative suggestion was made that the differences might be due to the confining nature of the submarine environment which permits no distant vision and requires constant accommodation and convergence.

The present investigation was undertaken to determine whether or not changes in visual ability may be ascribed to extended submarine service by retesting the vision of a sample of the original 1064 men. All tests and procedures were identical with those used in the original investigation.

## TESTS AND PROCEDURE

The vision tests given the men were the standard battery of the Bausch & Lomb Ortho-Rater and the regulation Snellen acuity charts. The Ortho-Rater tests were given first, using the order, procedure and scoring methods as described in "Instructions MASTER ORTHO-RATER AND MODIFIED ORTHO-RATER.<sup>3</sup> These tests were monocular and binocular acuities at a simulated testing distance of 26 ft and at 13 inches and lateral and vertical phorias at the same distances. Uncorrected vision was used throughout the Ortho-Rater tests.

Measures of distance acuity using the Snellen charts were made at 20 ft in a vision alley which was painted light gray and illuminated so that the chart had the standard luminance of 15 ft-L. Uncorrected acuities of the right, left, and both eyes were tested; if the man wore glasses, all three tests were repeated with his correction.

Three Snellen charts with different arrangements of the letters were employed so the men could not memorize the orders. Directions given to the men were: "You are to read the chart from the top down as far as you can, taking not more than two seconds to report each letter. Keep both eyes open and read each line very carefully." A man was given credit for a line if he committed no more than one error.

In addition to the vision tests, each man was asked to provide a brief history of his past service life, particularly the number of years he spent on shore or on submarines since 1951.

Table I. Snellen acuity in 1951 of sample of 51 submariners.

	Right Eye		Left Eye	
	No.	%	No.	%
20/20 or better in each eye	46	90.2	43	84.3
20/25 or 20/30 in worse eye	5	9.8	8	15.7
Worse than 20/30	0	—	0	—

Table II. Average visual test scores of sample of 51 submariners.

Test	Mean	$\sigma$
Snellen Acuity*		
Binocular	1.10	.34
Right	.90	.32
Left	.91	.32
Ortho-Rater Acuity—Far*		
Binocular	.92	.20
Right	.89	.19
Left	.89	.20
Ortho-Rater Acuity—Near*		
Binocular	.79	.26
Right	.77	.26
Left	.86	.30
Phorias		
Far Lateral	+1.94 $\triangle$	2.88
Far Vertical	0.38 LH	.40
Near Lateral	-0.21 $\triangle$	4.30
Near Vertical	0.05 RH	.26
Age	39.8	4.14
Years in Submarines	8.5	3.15

\*Visual acuity units used throughout this study are the reciprocals of the minutes of visual angle subtended by the test objects.

Table III. Correlations among various measures.

	Snellen Acuity	Ortho-Rater Far-binoc.	Ortho-Rater Near-binoc.	Age
Ortho-Rater Far	.84*			
Ortho-Rater Near		.16		
Age	-.12	-.14	-.55*	
Yrs in subs	-.25	-.10	.24	-.43

\*Significant at the .01 level

## SUBJECTS

The men in the original sample were all serving aboard Atlantic Fleet submarines at the time of the tests in 1951. Of the 1064 men, 7.6% were officers and the median age of the total group was 25.5 years.

The current sample was obtained by running the serial numbers of the original group through the computer at the Naval Medical Data Processing Center in Washington, D.C., to locate all those who were still in the Navy. The sample was further restricted, in that only those men who were currently stationed on the east coast of the United States and available during the spring of 1966 were tested. This resulted in the retesting of 51 men from the original group. Of these men, 25% are officers and their current median age is 39. The sample thus differs in that it contains more officers than the original group; also the median age of the 51 men in 1951 was slightly younger, 24 years.

The Snellen acuity of these men, as tested in 1951, was obtained from copies of letters transmitted to the Commanding Officer of each submarine at the end of the survey. These letters contained the names of the men who had 20/20 vision in each eye, those who had slightly lowered acuity, 20/25 or 20/30 in the poorer eye, and the acuity of those with poorer than 20/30. The latter group was asked to come in for a refraction at that time; however none of our sample of 51 fell into this category. The number of men in the current sample falling into these various categories in 1951 is tabulated in Table I.

## RESULTS

Table II presents the overall results of the visual retests of the 51 submariners, with the means and standard deviations for the acuity scores, phorias, age, and time assigned to a sea-going submarine. Correlations among the various tests and measures are tabulated in Table III.

The results show many points of similarity with the literature on testing visual acuity: binocular acuity is somewhat better than monocular,<sup>4</sup> the Snellen measure gives larger values than the Ortho-Rater in this acuity range,<sup>5</sup> and the correlation between Snellen and Ortho-Rater Far acuity test is high.<sup>6</sup> The correlations for binocular acuity and either years in submarines or age, while properly negative, are non-significant. Near acuity and age, however, are correlated as is predicted for an age group entering into presbyopia. The presence of 13 officers in the sample accounts for the negative correlation found between age and years in submarines. The officers were older but had less time in submarines than the rest of the group.

While typical in these respects, the data show subnormal acuities, compared either to general norms or to the mens' own acuities 15 years earlier. With the exception of the Snellen binocular, all the mean acuities at both testing distances are below the level (1.0 V.A.) generally considered normal. This is further portrayed in Figures 1-3 in which the acuities of the 51 men in 1966 are compared to the distributions found with the 1064 men in 1951. In every frequency distribution the recent acuities have shifted toward the poorer end of the values. In the case of Snellen binocular, the acuity shift has been from a high peak at the excellent acuity value of 20/13 toward the lower 20/20 to 20/15 level.

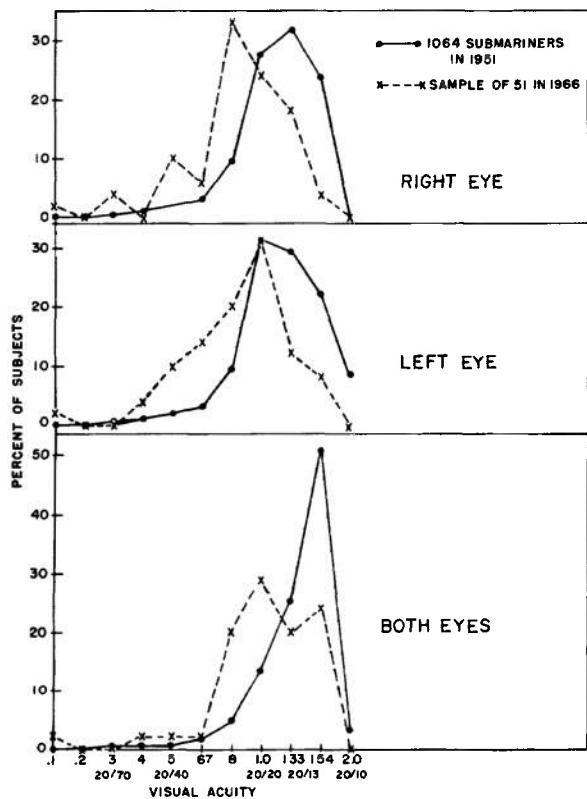


Fig. 1. Comparison of the percentage of subjects attaining various acuity levels in 1951 and 1966 using the Snellen test.

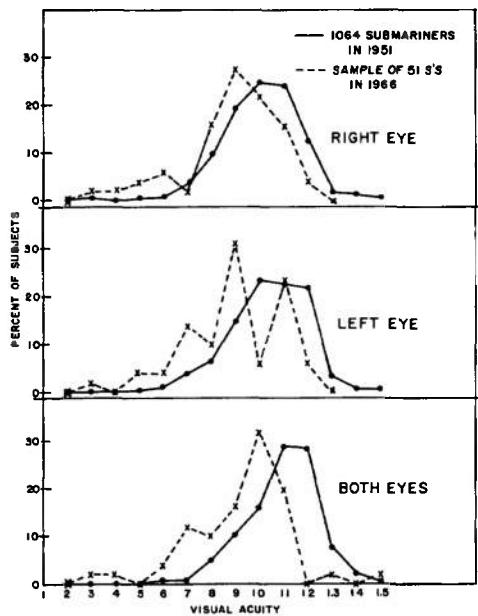


Fig. 2. Frequency distributions of Ortho-Rater scores at the far distance in 1951 and 1966.

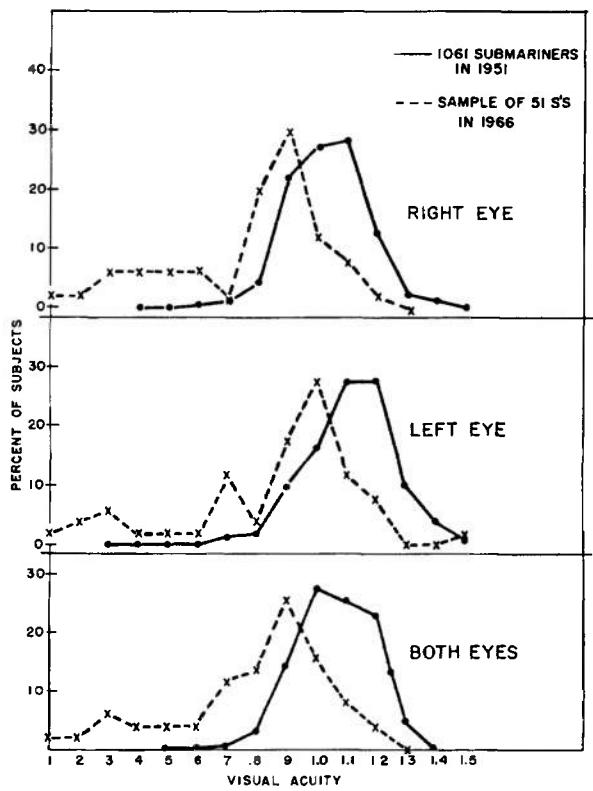


Fig. 3. Frequency distributions of Ortho-Rater scores at the near distance in 1951 and 1966.

Frequency distributions for the phoria measures are presented in Figs 4-7. In each case, two comparisons are made. In A, the per cent of the men with given phorias in 1966 is compared with the total distribution of scores for the 1064 men in 1951. In B, the current data are compared with the results of major studies of phoria tests done with the Ortho-Rater. These are measures made on 1426 visitors to the San Diego County Fair,<sup>4</sup> 250 Naval aviators and 1000 enlisted men,<sup>7</sup> 2354 candidates for Submarine School and 2179 experienced submariners being reassigned.<sup>6</sup> An envelope has been drawn around these five distributions and is pictured as the shaded areas in the figures.

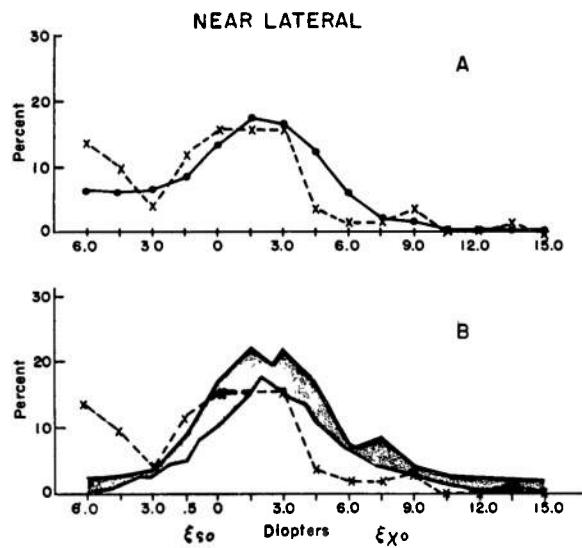


Fig. 4. Near lateral phoria scores of the 51 submariners compared in (A) with those in 1951 and in (B) with results of numerous large experiments on phoria.

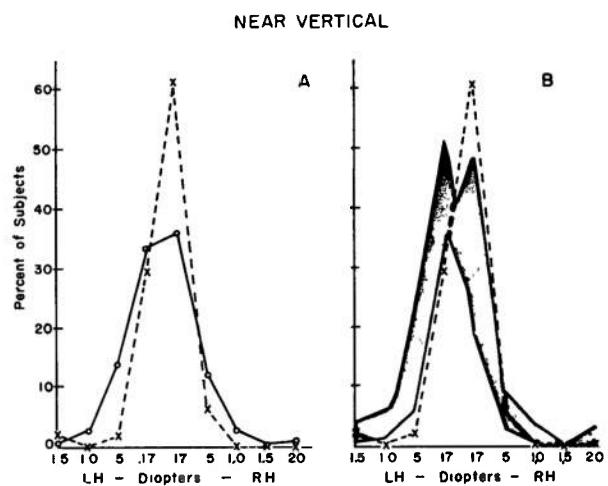


Fig. 6. Near vertical phoria scores of the 51 submariners compared in (A) with those in 1951, and in (B) with results of numerous large experiments on phoria.

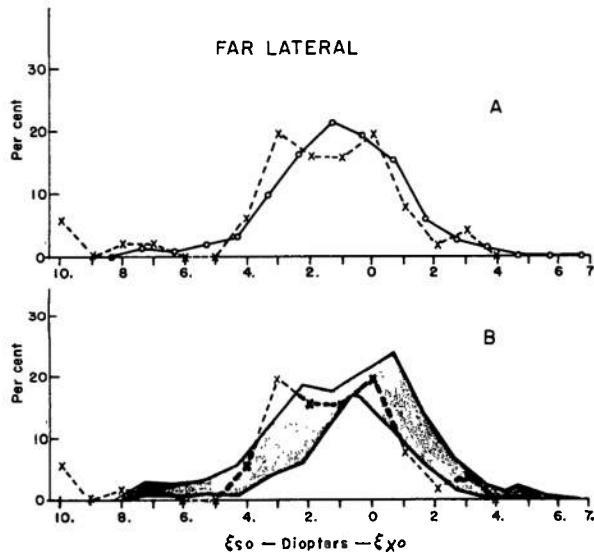


Fig. 5. Far lateral phoria scores of the 51 submariners compared in (A) with those in 1951, and in (B) with results of numerous large experiments on phoria.

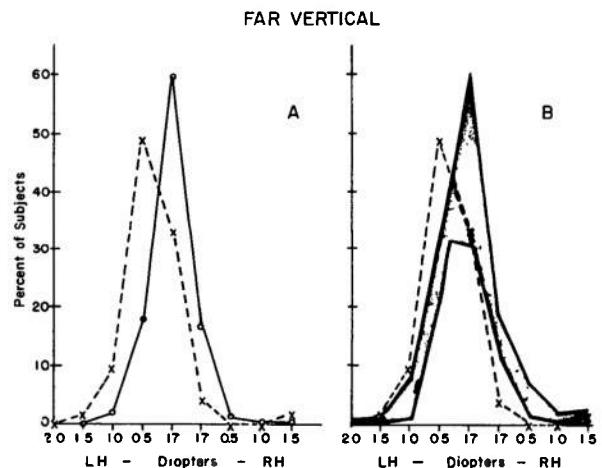


Fig. 7. Far vertical phoria scores of the 51 submariners compared in (A) with those in 1951, and in (B) with results of numerous large experiments on phoria.

For the lateral phorias, the distribution of our sample lies to the left or esophoric side of both the 1951 testing and of the means of all the other samples.

Some differences in the vertical phorias, Fig. 6 and 7, are also apparent, but these are small, less than  $\frac{1}{2}$  diopter, and well within the range generally considered normal.

## DISCUSSION

The changes that have occurred in the mens' acuities and phorias are apparent; however, in order to properly evaluate them, two questions must be answered: (1) is our sample of 51 men representative of the total group of 1064, and (2) are these changes due simply to an age factor, i.e. the men are 15 years older.

The first question can be answered simply by reference to Fig. 8 in which the percentages of men who reached various

criterion-levels of visual performance are compared. The curves for our sample of 51 men are almost identical to the curves for the total sample of 1064 men when all the testing was done in 1951. There is nothing in the data, therefore, to indicate that our sample of 51 contains more men with poorer acuity than the total group. On the other hand, the distribution of acuities for the same sample of 51 in 1966 is obviously quite different.

In order to determine whether or not the deterioration is simply the result of the submariners being 15 years older, the results are compared with surveys found in the literature on the changes in acuity with age. There are a number of such surveys, usually of cross-sectional design, on very large groups of subjects. Great care must be exercised in employing such comparisons however, since the acuity tests, lighting, procedures, and scoring methods vary

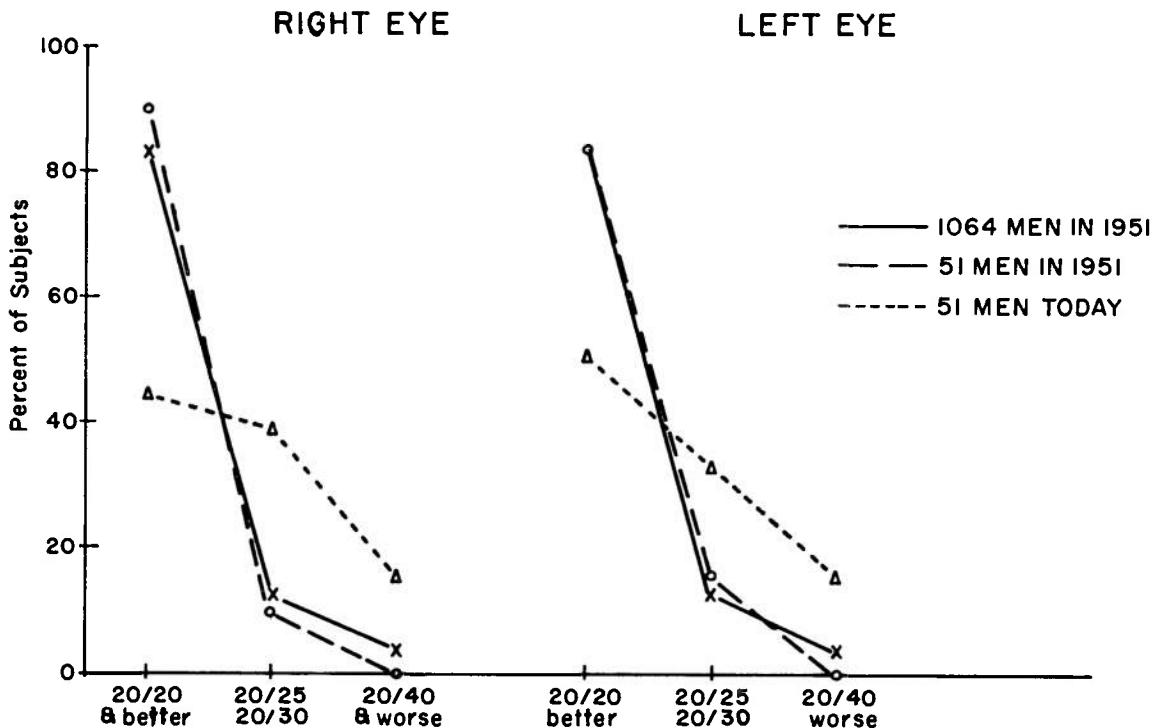


Fig. 8. Percentage of subjects achieving various Snellen acuities in the total sample of 1064 in 1951 and in the present sample of 51 tested in 1951 and today.

greatly and can influence the results considerably. Fortunately, our test battery included both Snellen and machine testing and both monocular and binocular measures, so that the appropriate values can be compared in each case. Data samples from only male subjects were studied.

Two studies on different samples, 10,000 industrial workers<sup>8</sup> and 220,000 life insurance holders<sup>9</sup> are shown in Fig. 9. The ordinate in each case is the percentage of the subjects having uncorrected Snellen acuity of 20/20 or better in each eye. The percentage of our sample of 51 men having 20/20 or better in each eye in 1951 and in 1966 are plotted for comparison. While the submariners were much better than average in 1951, as is to be expected since they represented a visually selected population, their Snellen acuity today is worse than that predicted for their age group.

Another comparison is shown in Fig. 10 for the machine acuity tests.<sup>10</sup> The data are from a Public Health Survey on subjects using the Sight Screener test and give the percentage of subjects with binocular acuity of 20/20 or better. Our data, the percent with binocular acuity of 20/20 or better, using the Ortho-Rater are given for comparison. The Sight Screener and the Ortho-Rater are similar screening devices which can be used interchangeably according to a careful assessment of their reliability and validity.\* Once again the submariners show a greater loss than would be predicted for their group.

A final comparison is given in Fig. 11 which shows the average binocular acuity, as measured on the Ortho-Rater of 772 males attending the San Diego Fair.<sup>4</sup> Here the acuity test is the same as ours; the authors tabulated the average binocular

acuities by age groups for all males who do not wear glasses; we have calculated the same statistic. Once again the acuity of the submariners is poorer than that of other men in the same age group.

As far as phoria is concerned, there is no predictable change in direction to be expected with age. Kephart and Oliver<sup>11</sup> summarized the available studies and computed correlation coefficients between age and lateral phoria, as measured on the Ortho-Rater, for 8,000 individuals between 16 and 78 years of age. The correlations for males were .039 toward esophoria at the far distance and .178 toward exophoria at the near distance.

A similar conclusion is reached in the Lichtenstein's study: "Phoria trends with age are not very marked. About the only thing that can be said with confidence is that anomalies are most evident in the over-60 age group."<sup>4</sup> (p. 34)

The conclusion from each of these comparisons is that, not only do the men have poorer acuity and more esophoria than they did in 1951, but also the changes are greater than any predicted for their age group. This is true of monocular and binocular acuities at both near and far, as tested on both the Ortho-Rater and the Snellen charts, and of near and far lateral phorias. The results of the previous study are therefore upheld and some support given to the proposition that the continued close work in the submarine environment might be responsible.

In an attempt to provide further understanding, the 51 men were categorized into three groups on the basis of their results on all the acuity tests. One group was comprised of all those individuals with normal far acuity and for whom the results

\* The data comparing acuities as measured by the two instruments does show slightly higher values (average ratio SS/OR = 1.068) for the Sight Screener.<sup>5</sup> The data have been corrected for this difference in Fig. 10; no change is made in the interpretation however since both the 1951 and the 1966 data must be corrected.

on the near Ortho-Rater acuity tests were within  $\pm 1$  step of their far scores. Group 2 was designated as presbyopes on the basis of Ortho-Rater near scores poorer than far by 2 or more units; their vision otherwise appeared normal. The remainder of the individuals were placed in the third group; of these 10 were easily categorized as myopic and 8 had slightly reduced acuity at both near and far. These data are given in Table IV.

Comparison of the ages of the three groups showed those with tendencies to presbyopia were, on the average, 5 years older than the rest. This group also included over one-half of the officers who were somewhat older (average age = 43.1) than the enlisted men (age = 38.7). The group with lower acuity was, however, the youngest of all, but even though younger, had spent the most years attached to submarines.

Loss in visual ability in middle age is generally attributable to presbyopia or a loss of accommodative powers. Studies relating age, acuity, and refractive error<sup>12-14</sup> have shown that the acuity of myopes and astigmats does not change much after the mid-twenties until the late fifties and it is fairly unusual for myopia to develop after this age. Nonetheless occasional cases do occur.<sup>15</sup> The reasons for developing myopia at any age are obscure. Environmental causes for myopia have long been debated<sup>16</sup> and perhaps can never be proved due to the difficulty of factoring out the effects of natural selection. Thus certain groups who perform considerable close, visual work, as college students, Naval Academy cadets,<sup>17</sup> and school children,<sup>18</sup> often show increasing degrees of myopia. The question of whether the close work caused the myopia or whether individuals with inherent tendencies to myopia tend to select occupations involving close work has never been resolved. The argument, in this case, that persons with tendencies for increasing myopia tend to stay in the Navy seems rather more tenuous.

Table IV. Current sample of submariners categorized as to type of defect.

	Normals	Presbyopes	Others
Number	16	17	18
Snellen binocular (mean V.A.)	1.33	1.05	.96
Ortho-Rater Far (mean V.A.)	1.06	.89	.83
Ortho-Rater Near (mean V.A.)	.94	.51	.98
Age	38.7	43.2	37.5
Years in Subs	7.9	7.9	9.7

Thus the evidence indicates a distinct possibility of visual loss due to long-term close work. However, it should be noted that the major comparisons of acuity and phoria as a function of age were with cross-sectional studies, that is, studies which test different groups at each age level. This general procedure is contrasted with the present longitudinal study where the same individual was followed from one age level to another. For predicting individual changes and determining causal relations, longitudinal studies are preferable but not generally available in the literature. Thus a continuing surveillance of the vision of submariners over a period of time is planned and comparisons performed with longitudinal control studies.

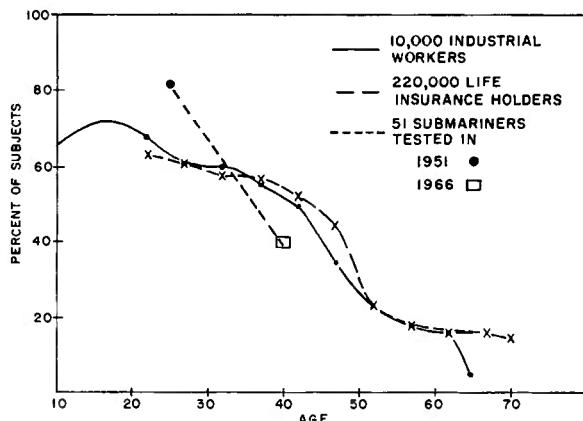


Fig. 9. Per cent of males with Snellen acuity of 20/20 in each eye, as a function of their age.

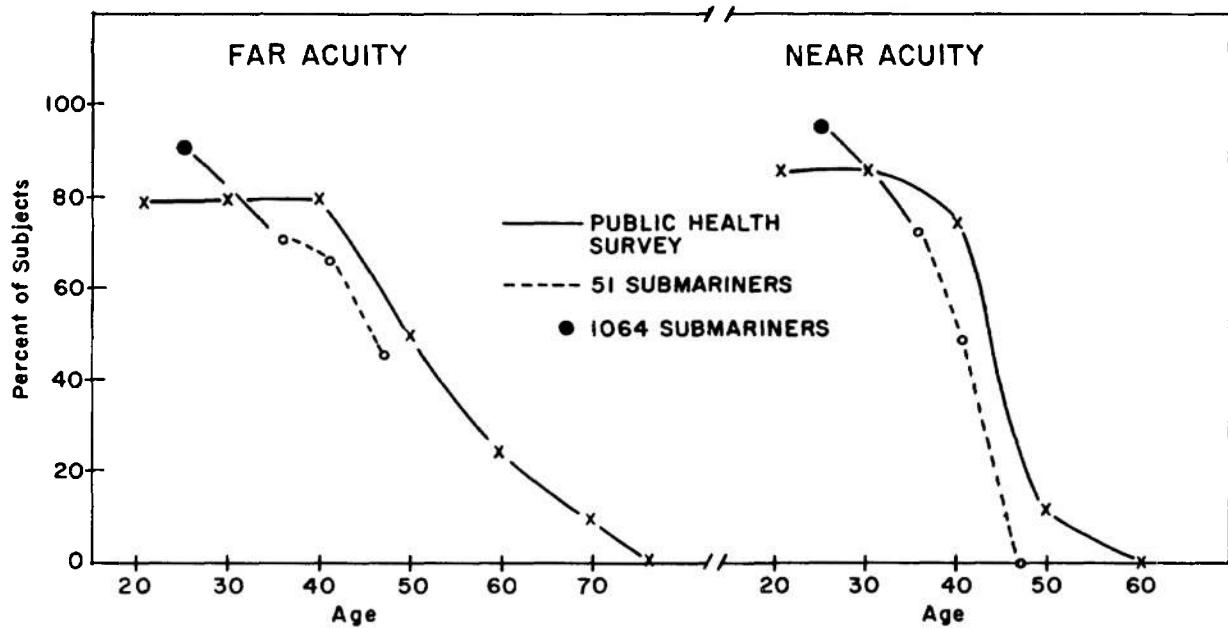


Fig. 10. Per cent of males with 20/20 or better binocular vision as measured on Screening instruments, as a function of age.

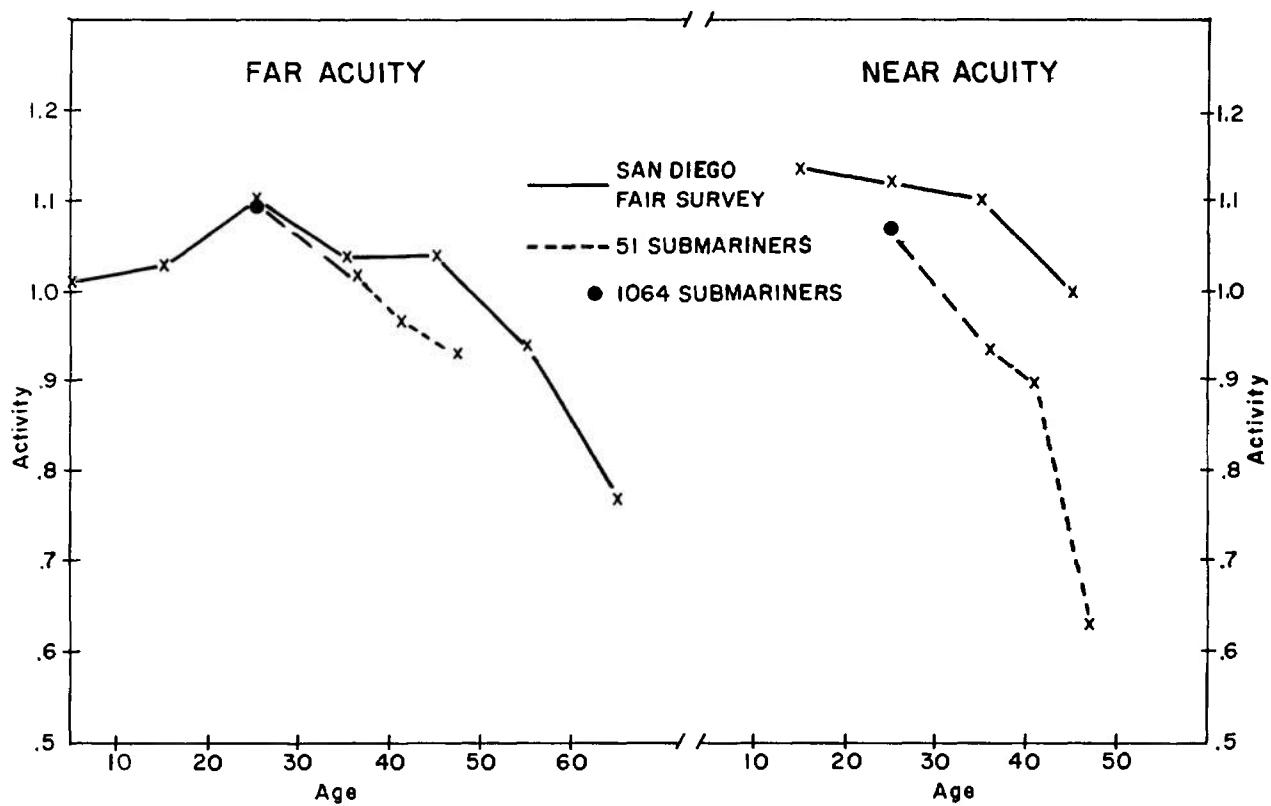


Fig. 11. Average binocular acuity of males, who do not wear glasses, as measured on Ortho-Rater, shown as a function of age.



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Donald O. WEITZMAN, Jo Ann S. KINNEY, and Alma P. RYAN

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**11 SUPPLEMENTARY NOTES****12 SPONSORING MILITARY ACTIVITY**  
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It was found that certain changes have taken place over the 15 year period, most notably, a loss of visual acuity, at both near and far, and a tendency toward esophoria. While some decrement in vision is expected as a function of age, these changes are larger than that predicted for men of their age level.

The suggestion has been made previously that the confining nature of the submarine with the constant requirement for accommodation and convergence might cause a visual impairment. This possibility, and other conceivable influences, will be evaluated in further longitudinal studies of submariners and non-submariners. Preventive measures will also be assessed.

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